Notes on the Biology of the Wahoo in the Line Islands

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Incidental catches of wahoo, *Acanthocybium solandri* (Cuvier and Valenciennes), have been made by the Pacific Oceanic Fishery Investigations, a branch of the U. S. Fish and Wildlife Service, during experimental tuna fishing conducted from 1950 to 1956. The exploratory fishing, which extended from 180° to 130°W. longitude and from 10°N. to 13°S. latitude, has been carried out both close to the islands and in the open sea. The bulk of our wahoo data came from the Line Islands, which from south to north are: Starbuck, Malden, Jarvis, Christmas, Fanning, Washington, and Palmyra islands, and Kingman Reef. They extend in a general northwesterly direction from 5°S. latitude and 155°W. longitude to 7°N. latitude and 163°W. longitude. Although there is no organized fishery in the islands, the copra plantation workers (Gilbertese and Ellice islanders) use beach seines to capture a variety of lagoon and reef fishes and hand lines to catch an occasional tuna or wahoo.

Most of the published reports dealing with the wahoo are brief and are concerned primarily with its occurrence and distribution. The presence of wahoo was first noted in the Line Islands by Fowler (1938: 277). Rosa (1950: 75–77) lists a number of references which are of interest principally to taxonomists. In general the biology of the species is poorly known and has not been previously considered in the central Pacific.

The wahoo, a member of the order Scombriformes, is a slender, streamlined fish with a sharp pointed head (Fig. 1). The mouth is large and is armed with razor-sharp teeth. Wahoo may weigh over 130 pounds and reach a length of nearly 7 feet. The body is steel-blue above and pale blue below. A series of bluish-black vertical bars, which fade soon after death, are present on the sides of the body. These fish are said to be very rapid swimmers and to make spectacular leaps out of the water.

The species is cosmopolitan in tropical and subtropical areas, and ranges at least as far north as Hawaii, where it is called "ono." Jenkins (1904: 441) examined wahoo in the Honolulu Market and reported that, "This is the first record of the species in Honolulu." In Hawaii today the species is of some slight importance as a sport fish. It is also sold commercially on the fresh fish market in Honolulu, but is of secondary importance. In 1953 the catch of 50,813 pounds during the year was sold for $11,166.94.

METHODS

The majority of fish available for this study were taken on standard surface trolling gear which is described by Bates (1950). This method of trolling employs about six lines attached to two long poles extending outboard, one from either side of the vessel. Trolling was mainly carried out from approximately 200 yards to 3 miles from the fringing reefs of the various islands. Some catches were also made on longline (flagline) gear, described by Niska (1954). Longline gear, which fishes well below the surface, was generally

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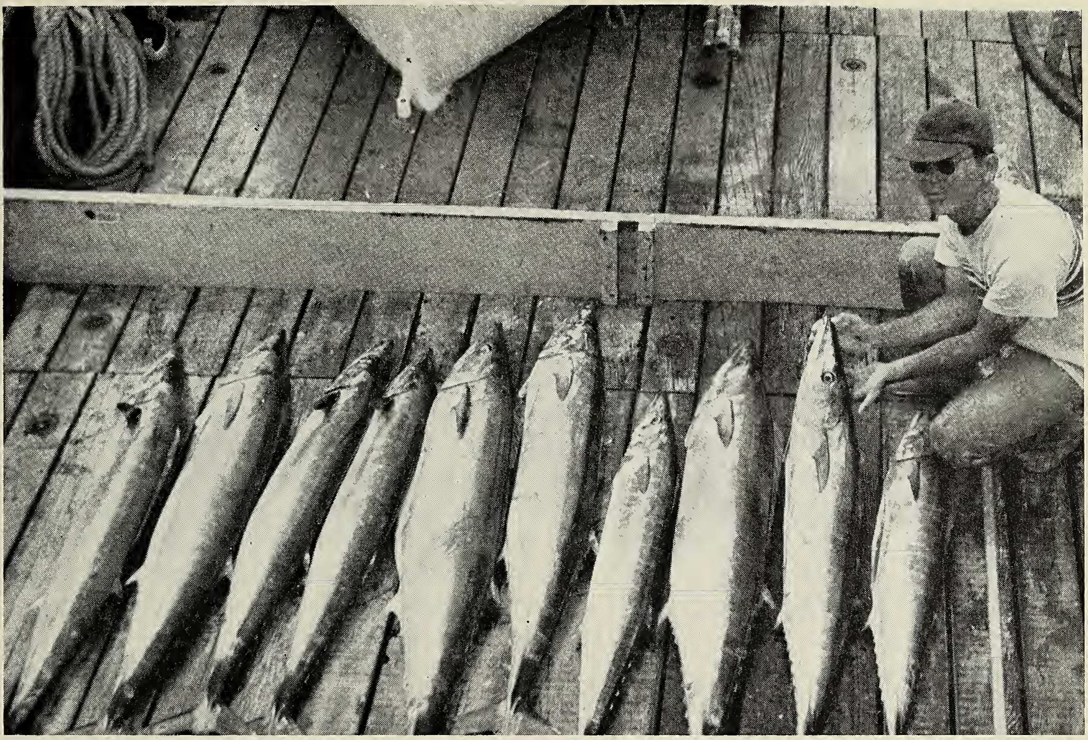

FIG. 1. Wahoo captured by surface trolling in the Line Islands.

used in the open ocean, but some longline stations were occupied as close as 5 to 10 miles from land.

Length measurements were made in millimeters, using calipers. The fixed arm was placed on the tip of the upper jaw with the mouth closed, and the sliding arm of the caliper was placed at the fork of the caudal fin, being careful to depress the fleshy flap (Marr and Schaefer 1949: 242). Weights were taken in pounds, using a steelyard rigged to a davit on the deck of the vessel. Some difficulty was encountered in accurately weighing the fish when the vessel was under way, but most weights were taken when the vessel was in smooth waters or at anchor.

In preparing length-frequency distributions the lengths were first combined in 4-cm. groups and then smoothed by a moving average of three. Modal groups in these distributions are defined as the size classes with the highest frequencies in the smoothed distributions. Where several adjacent size classes are similar in height after smoothing, the center of these size classes is designated as the mode.

Stomach contents of the fish were recorded in the field as soon as possible after the fish were captured. The few parasites returned to the laboratory for examinations were preserved in 10 per cent formalin.

Measurements of ova for spawning and fecundity analysis were made with a dissecting microscope, employing a micrometer eyepiece measuring in units of 0.023 mm. The eggs were not perfectly symmetrical, so to avoid selection the "diameter" measured was the distance between two lines of the micrometer tangent to the eggs, the micrometer being held in one position during a series of measurements, following the method of Clark (1934: 7).

AVAILABILITY

Wahoo do not appear to form large compact schools. This simplifies the problem of estimating their availability. Kishinouye (1923: 412) states that wahoo do not "make a school." Taylor (1951: 278), in discussing wahoo off North Carolina, reports that they do not form schools but that males and females group in pairs at spawning time. From our trolling catches close to shore it seems that this species tends to form small, loose, feeding aggregations, since we found that occasionally several wahoo would hit the lures simultaneously. Chapman (1946: 166) believes that they may form schools, for some of the wahoo he caught near Palmyra Island had frayed caudal fins, which he attributed to crowding in schools.

Some general knowledge of the vertical and horizontal distribution of wahoo is important when estimating the availability of this species. These aspects of the distribution can be roughly inferred from a comparison of longline catches and troll catches. The longline catches are small both close to land and in the open ocean. For example, Murphy and Shomura (1953*a*, 1953*b*, 1955) and Shomura and Murphy (1955) record only 59 wahoo captured on 14 POFI experimental longline fishing cruises involving numerous stations, some close to land. This figure suggests that wahoo are never abundant at the depths fished by this gear (200–600 ft.). Trolling operations were much more productive, but only close to land. Only 12 wahoo were caught during 5,500 hours of surface trolling in the open sea, more than 60 miles from land (Murphy and Ikehara 1955: 14). In contrast, within a few miles of land in both the Hawaiian Islands and Line Islands surface catches have averaged about 1 wahoo per hour (Table 1). From this information we infer that the wahoo prefer shallow depths and are more abundant close to land.

Even near islands wahoo are not very abundant in the central Pacific. This is suggested by the low catch rates from surface trolling around the Hawaiian and Line islands (Table 1). The troll catches obtained near the Line Islands during all seasons of the year indicate that the species does not occur there in sufficient numbers to support a profitable commercial fishery. This is also true in Hawaii (Welsh 1949*b:* 29). Neither does the wahoo appear to be very abundant in the Atlantic, at least off North Carolina, where Taylor (1951: 278) states that the population is small.

It is interesting to note from the Line Islands data (Table 1) that wahoo and yellowfin tuna, *Neothunnus macropterus* (Temminck and Schlegel), have a similar pattern of seasonal variation in availability. This similarity could indicate that environmental or other factors

TABLE 1

Results of surface trolling for wahoo and yellowfin tuna in waters of the Hawaiian and Line Islands

TIME	HOURS TROLLED	AVERAGE NUMBER OF LINES	WAHOO		YELLOWFIN	
			Number	Catch per hour	Number	Catch per hour
Hawaii						
Year around, 1947–48 (Welsh 1949b)	307	7.0	20	0.07	23	0.08
Line Islands						
April-June 1950 (Bates 1950)	285.5	6.1	178	0.62	882	3.09
March-April 1955	142.5	5.0	274	1.92	438	3.07
May-June 1955	116.0	6.0	135	1.16	100	0.86
July-August 1955	105.0	6.0	83	0.79	24	0.25
September-October 1955	182.0	6.0	245	1.35	171	0.94
November-December 1955	108.0	6.0	144	1.33	64	0.59
January-February 1956	133.5	6.0	267	2.00	148	1.10

influence both species similarly and are of greater importance than inter-specific competition for food, though both appear to feed on similar animals.

REPRODUCTION

In samples from the Line Islands, at all times of the year the percentage of males tends to be higher in the northern islands than in the southern islands (Fig. 2). This consistent trend or gradient suggests a migration of wahoo to maintain itself, unless there is varying differential mortality between sexes among areas, which seems unlikely. Such a gradient might be related to spawning movements but we are unable to describe them.

The wahoo in the Line Islands appear to spawn over an extended period of time, as is common with fish found in tropical waters.

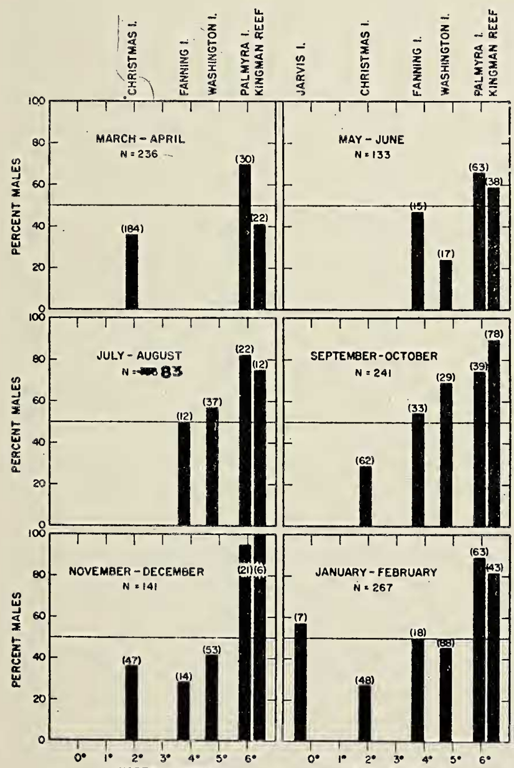

FIG. 2. Percentage of male wahoo by trolling areas, March 1955 to February 1956. (The number in each sample is shown in parentheses).

Cursory field examination of 80 females in March and of 143 in November and December, using categories devised by Marr (1948: 201),—i.e., immature, ripening, ripe, spawning, and spawned out—revealed all stages of maturity during both periods.

In order to estimate the number of eggs per spawning the size frequency distribution of ova in an apparently ripe ovary was determined for a fish of 131 cm. fork length (Fig. 3). Only eggs larger than 8 micrometer divisions, or 0.184 mm., were measured. An abundance of undeveloped or primitive eggs was present in the ovary, but most of these were not measured. The group 0.184–0.46

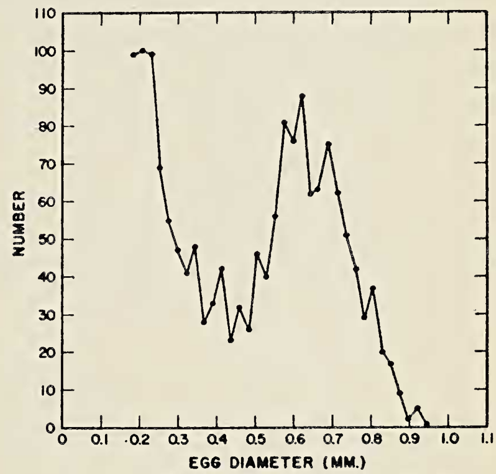

FIG. 3. Frequency distribution of egg diameters from a single female, 131 cm. fork length, captured May 1955 at Fanning Island.

mm. contained the larger of these "stockpile" eggs; the group from about 0.46 mm. to 0.94 mm., with a prominent mode at 0.62 mm. appeared to be maturing eggs. This latter group of eggs may be likened to the "type B" or developing eggs described by Tester and Takata (1953: 42) from the aholehole, *Kuhlia sandvicensis*. This one specimen showed no clear evidence of more than one mode among the developing eggs. The maturing group of eggs (> 0.46 mm.) in the ovaries of this female wahoo was estimated to number about 6.1 million. This estimate was obtained by weighing the formalin-preserved (wet) ovaries, weighing a wedge-shaped section from one of the ovaries, and counting the number of eggs in the most mature group in this sample. The total number of mature eggs in both ovaries was then calculated by simple proportion.

This estimate of 6.1 million eggs per spawning is comparable in order of magnitude to the amount of spawn released by some other related species. Yuen (1955: 18) computed the number of eggs extruded in one spawning of a bigeye tuna, *Parathunnus sibi* (Temminck and Schlegel), in the Pacific to be 2.9 to 6.3 million; June (1953: 63) estimated the number of eggs per spawning of a yellowfin sampled in Hawaii to be 2 to 8 million. Both authors found that the number of eggs spawned increased, in general, with increase in size of fish. This probably holds true for the wahoo.

FOOD HABITS

Of the 235 stomachs examined, 115 (48.5 per cent) were empty. This relatively large number of empty stomachs may be due to regurgitation on capture. The wahoo struggles violently on the trolling line and may regurgitate food while being landed and killed. As some of the stomach contents were probably incomplete, an elaborate analysis of the food based on percentage by volume was not undertaken. Rather the analysis was confined to frequency of occurrence of the various food items.

Fish remains have a high frequency of occurrence among the food items (Table 2), and perhaps beyond their true significance since fish bones are slow to digest and hence persist longer in the stomachs than readily digested items. In both time periods (March, and November–December) mackerel scad, squid, and skipjack appear to be of importance in the food, with mackerel scad being the major item.

A much greater variety of food than is indicated by Table 2 is probably consumed by the wahoo. Very small items could have been overlooked. On infrequent occasions specimens were on deck for several hours prior to the examination of the stomachs, and the

TABLE 2
STOMACH CONTENTS OF 235 TROLL-CAUGHT WAHOO CAPTURED DURING MARCH, AND NOVEMBER-DECEMBER, 1955

FOOD ITEMS	FREQUENCY OF OCCURRENCE		PER CENT FREQUENCY OF OCCURRENCE	
	March	November-December	March	November-December
Items identifiable				
Squid (*Loligo* sp.)	6	3	18.2	13.0
Skipjack (*Katsuwonus pelamis*)	4	6	12.1	26.1
Pomfret (Bramidae)	1	1	3.0	4.4
Puffer (Tetraodontidae)	2	2	6.1	8.7
Mackerel scad (*Decapterus* [*psinnulatus*])	19	9	57.5	39.1
Flying fish (*Cypselurus* sp.)	1	..	3.0	...
Lantern fish (Myctophidae)	..	1	...	4.4
Sunfish (*Ranzania truncata*)	..	1	...	4.4
Total	33	23	99.9	100.1
Entire sample				
Empty stomachs	34	81	39.1	54.7
Fish remains not identifiable	20	44	22.9	29.7
Food remains identifiable	33	23	37.9	15.5
Total	87	148	99.9	99.9

identity of the more readily digestible forms could be lost during this time. Aside from these difficulties, it seems likely that the data in Table 2 provide a reasonably good picture of the food throughout the year. We do not believe there is much seasonal change in the fauna of the tropical Pacific.

The results of other studies suggest the diet of wahoo is similar throughout its range. Welsh (1949*a:* 22) made a preliminary examination of the food of wahoo in the Hawaiian Islands, using a rating system which considered total bulk of food, total number of food items, and the total number of times food was found in individual stomachs. Of the 17 stomachs he examined, 10 were empty. Those containing food held fish and squid. The food habits of the wahoo near Japan would seem to be nearly the same as in the Line Islands, for Kishinouye (1923: 412) states that they "feed on calamaries [squid] and pelagic fish."

LENGTH FREQUENCY ANALYSIS

An examination of the sizes of wahoo in our catches will contribute to our understanding of the biology of this species. In the Line Islands we sampled only a segment of the known size range of the species for small fish were not taken and much larger sizes have been recorded from other areas. Hosaka (1944: 69) reports a 124¾-pound wahoo taken on sport fishing gear off the island of Oahu, and LaMonte (1952: 9) reports a world record for wahoo as 133½ pounds (6 ft., 11 in.) caught in the Bahamas in 1943.

The size distribution of longline-caught wahoo is similar in most respects to that of fish taken on trolling gear. The longline catches, most of which are from the open sea, were made over several years at all months of the year and show a prominent mode at 128 cm. and a lesser mode at 146 cm. (Fig. 4). These fish range from 54 to 198 cm., with the majority between 106 and 162 cm. The measurements of troll-caught wahoo, taken mostly within 3 miles of land, during 1950,

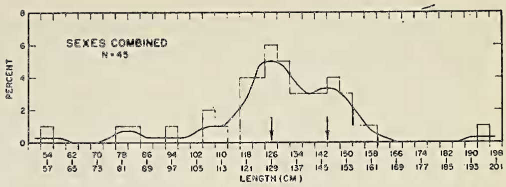

FIG. 4. Size frequency distribution of longline-caught wahoo, October 1950 to March 1955. (Smoothed by a moving average of three.)

1951, 1955, and 1956 show a similar size range, from 98 to 174 cm., and a similar distribution of sizes. It would appear then that both fishing methods sampled the same segments of a common population.

Samples of wahoo from some islands show differences in length distribution between sexes. An example of this in distributions of wahoo taken at Christmas Island during March and April 1955 (Fig. 5) shows a slight displacement of modes. In the male distribution there is a small mode at approximately 114 cm. and a dominant mode at approximately 134 cm.; in the female distribution there is a dominant mode at about 128 cm.

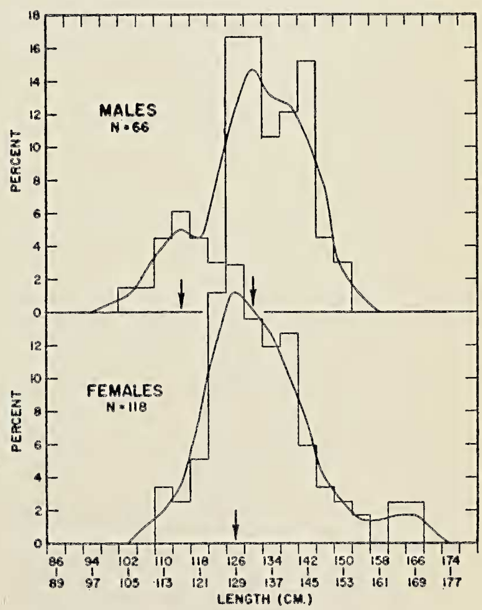

FIG. 5. Size frequency distribution of troll-caught wahoo from Christmas Island during March-April 1955. (Smoothed by a moving average of three.)

and a suggestion of a mode at approximately 164 cm. This suggests a differential growth rate between the sexes.

Wahoo show size variation associated with changes in latitude, as has been described for other scombrid fish. For example, Nakamura (1952: 101) found that the average weight of yellowfin tuna increased with latitude both to the north and south of the equator between the west coast of Sumatra and the Nicobar Islands. With respect to wahoo, the relative abundance of the larger fish appears to decrease from Christmas Island in the south to Palmyra Island and Kingman Reef in the north. This is accompanied by an increase in the numbers of smaller fish from south to north, these trends appearing in both the male and female length distributions (Fig. 6). The indications are that the wahoo are not distributed over the area in random fashion with respect to either size (Fig. 6) or sex (Fig. 2). Unless each area has a separate population with a different growth rate and sex ratio, there must be differential movement of individuals or groups in order to maintain the observed size and sex gradients. This movement, however, need not necessarily be confined to the study area.

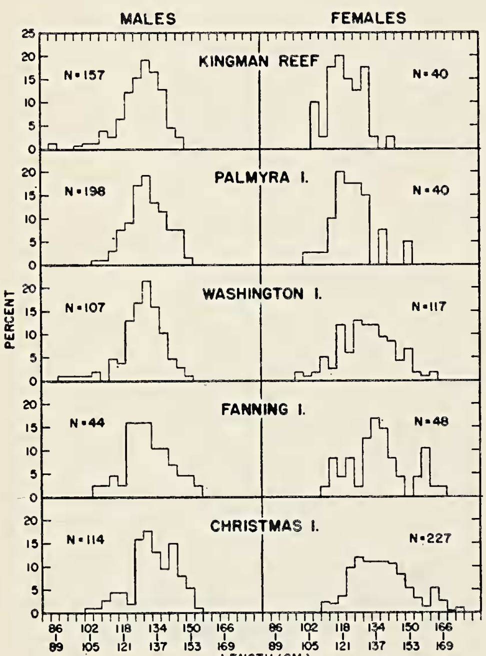

FIG. 6. Length frequency distributions of wahoo by areas, March 1955 through February 1956.

This nonrandom distribution of the wahoo makes it almost impossible to study growth by the method of progression of dominant modes in size frequencies because of the great difficulty in obtaining representative samples. Therefore such studies were not attempted.

LENGTH-WEIGHT RELATIONSHIP

As no significant difference in the length-weight relationship was noted between sexes, the data were combined to calculate the following regression equation which describes this relationship in the wahoo: Log weight = $-9.4199 + 3.50583$ log length, where weight is in pounds and length in millimeters. The mean weights for given lengths may be determined from the smooth curve shown in Figure 7. This large exponent, 3.50583, reflects the elongate, slender shape of the wahoo. As one would expect for a fish of this shape, a small increase in weight yields a relatively large increase in length. On the other hand

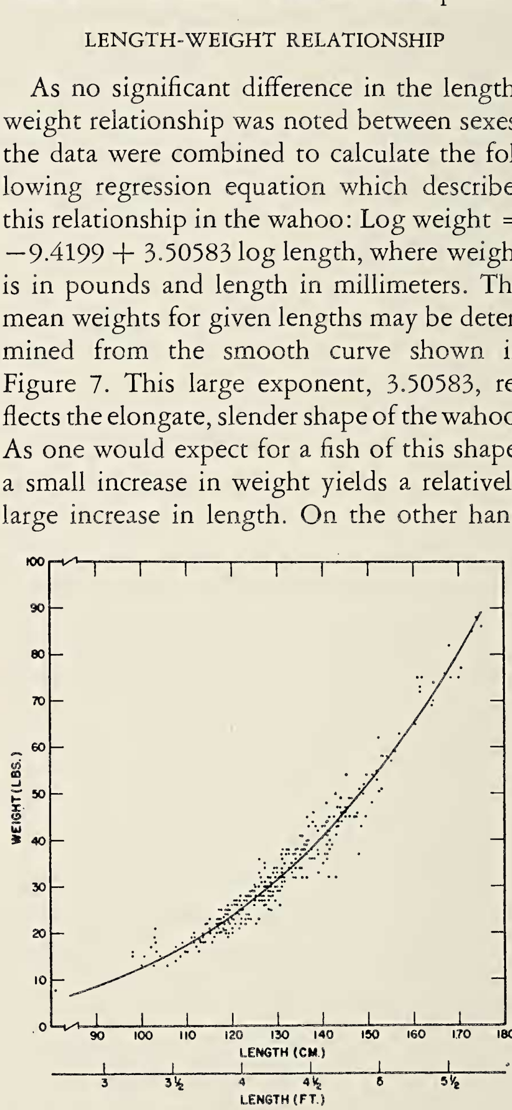

FIG. 7. Length-weight relationship for wahoo from the Line Islands, February 1951 to June 1955. Regression curve fitted by the equation: Log weight = $-9.4199 + 3.50583$ log length.

stout-bodied fish, such as some of the tuna, have a considerably smaller exponent. Examples are: yellowfin from Costa Rica, which have an exponent of 2.940 (Schaefer 1948: 119); and bigeye tuna, *Parathunnus sibi* (Temminck and Schlegel), sampled in Hawaii, which have an exponent of 2.9304 (Iversen 1955: 2).

PARASITES

Although no diligent search was made for parasites, the list given in Table 3 indicates that the wahoo is rather heavily parasitized. In the course of the examination of food items, trematodes about one inch in length when partially contracted were regularly noted at the posterior end of the stomach. Nigrelli and Stunkard (1947: 188) have carefully examined the genus *Hirudinella* and, on the basis of 33 specimens taken from wahoo captured in both the Atlantic and Pacific oceans, regard all forms of this giant trematode in the wahoo as belonging to a single species, *H. ventricosa* (Pallas).

In the 220 stomachs examined during March and November–December 1955 the number of giant trematodes per stomach ranged from 0–17 (Table 4). In all except the largest fish, two trematodes per fish were most commonly encountered, suggesting that this number represents a physiological equilibrium between host and parasite. On the other hand in the largest length group (160–179.9 cm.), four trematodes per stomach were commonly found.

SUMMARY

1. The availability of wahoo caught by trolling and longline fishing indicated the existence in the Line Islands of a small population that was most abundant in shallow water within a few miles of land.
2. Males were relatively more abundant in catches from the more northerly islands than in those from the more southerly islands.
3. Examination of wahoo gonads showed all

TABLE 3
Parasites of wahoo from the Line Islands, 1955

PARASITE	SITE OF INFECTION	NUMBERS PRESENT PER WAHOO	RATE OF INFESTATION	
			Per cent	Number of wahoo examined
Trematoda				
Neothoracocotyle acanthocybii (Meserve)[1]	Between gill filaments	Numerous	(high)	...
Didymocystis acanthocybii Yamaguti[1]	Head inside gill covers	Numerous cysts—2 worms/cyst	51.0	104
Hirudinella ventricosa (Pallas)	Caudal end of the stomach	0–17	98.2	220
Nematoda	Mass of worms embedded in belly wall	Many	(slight)	...
Copepoda				
Brachiella sp.	Within joint of pectoral fins	2 in each joint	98.3	118
Gloiopotes sp.	Outside surface of body and caudal fins	Many—variable	54.2	96
Pennella sp.	Embedded in belly wall with hind portion protruding	1 or 2	9.8	92

[1]Trematodes kindly identified by Dr. H. W. Manter, University of Nebraska, Lincoln.

TABLE 4
NUMBER OF GIANT TREMATODES IN STOMACHS OF WAHOO, BY HOST SIZE

NUMBER OF WORMS PRESENT	FREQUENCY OF OCCURRENCE BY HOST SIZE (CM.)							
	100–119.9		120–139.9		140–159.9		160–179.9	
	No.	%	No.	%	No.	%	No.	%
0	..	...	3	2.4	1	1.4	..	...
1	..	...	7	5.7	7	9.7	1	7.7
2	10	90.9	90	72.6	41	56.9	3	23.1
3	..	...	19	15.3	12	16.7	1	7.7
4	1	9.1	3	2.4	8	11.1	6	46.2
5	..	...	1	0.8	1	1.4	1	7.7
6	..	...	1	0.8	..	...	1	7.7
8	..	...	..	...	1	1.4	..	...
17	..	...	..	...	1	1.4	..	...
Total	11	100.0	124	100.0	72	100.0	13	100.1

stages of maturity present. The number of mature eggs in a single female was estimated at over six million.

4. The wahoo taken close to the islands showed little variety in their diet as judged by stomach contents. Of the identifiable food material the main items were mackerel scad, skipjack, and squid.
5. An examination of size frequency distributions from the Line Islands area revealed that the females attain a larger size than the males, and there is some suggestion that the two sexes grow at different rates. No attempt to estimate growth by modal progression is made since there are indications that the samples were not representative of a homogeneous population unit.
6. A length-weight relationship for wahoo from the Line Islands is given by the equation:

   Log weight (pounds) $= -9.4199 +$ 3.50583 log length (millimeters).
7. The wahoo was found to be parasitized by trematodes, nematodes, and copepods.

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